SAFETY NOTE 25
ESTIMATING PAST EXPOSURES TO AIRBORNE BERYLLIUM AT FERMILAB

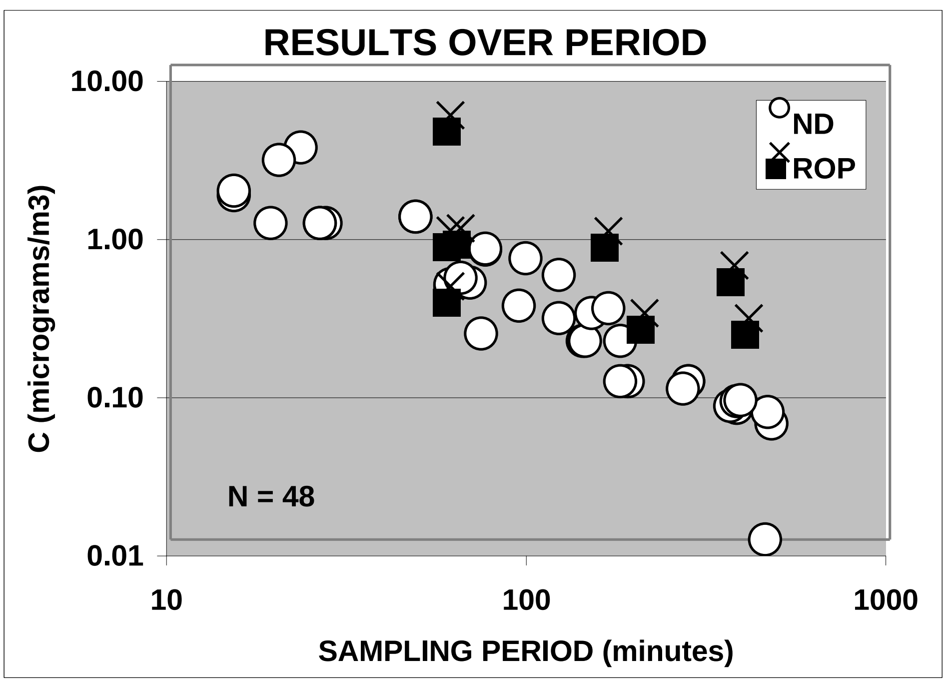
Tim Miller
Originally issued 9/28/00
Revised 1/5/01

INTRODUCTION

DOE's Chronic Beryllium Disease (CBD) rule requires that training be provided and that medical surveillance be offered to beryllium-associated workers. This includes all Fermilab employees who may have been exposed to airborne concentrations of beryllium in the past. In Safety Note 24, quantitative threshold exposure criteria were developed to aid in identifying this population (see below).

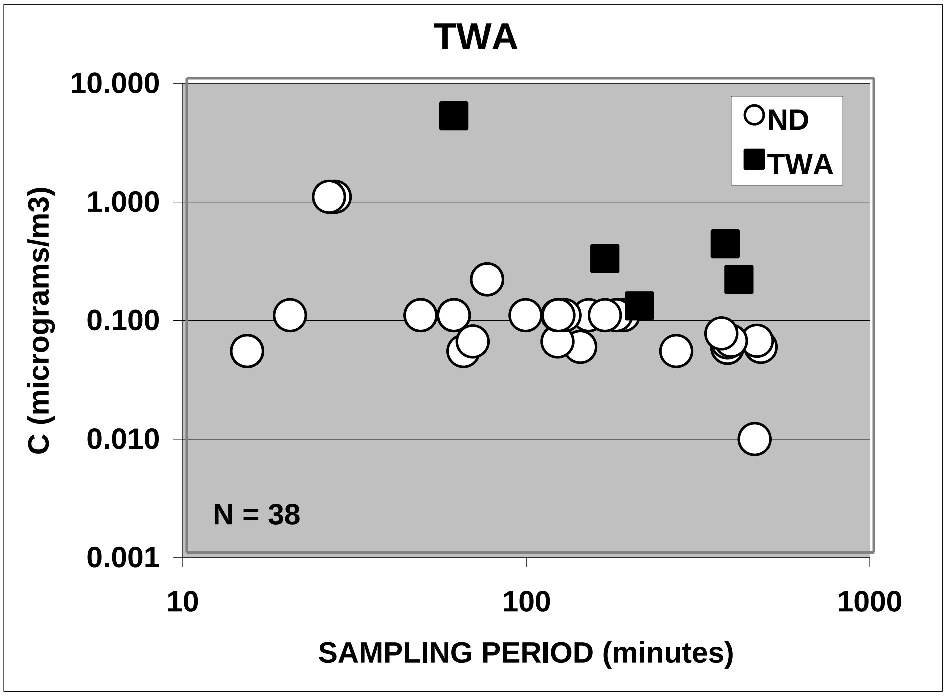
Description	Numerical limit	Time constraints
DOE action level (AL)	0.2 $\mu g/m^3$	8-hour TWA
EPA ambient air limit (AAL)	7.2 $\mu g\text{-}hr/m^3$	30 calendar days

Unfortunately, it is difficult to apply these limits since airborne beryllium has not been extensively monitored at Fermilab. This is not surprising since handling has been minimal, aerosol-producing activities have been severely restricted, and nearly all samples that have been collected came out well below 2 $\mu g/m^3$. Below is a log-log plot of sampling period concentration versus exposure duration for the 48 air samples that have been collected at the Lab.



Only eight (17%) had detectable levels of beryllium, shown as black squares. The graph also demonstrates the inverse concentration-time relationship for the *detection threshold* that is expected at a constant sampling rate of ~2 lpm and constant analytical sensitivity of 0.1 μg (ND - open circles).

A TWA could be calculated for 38 of the samples (see below). Only five of these (13%) showed detectable levels of beryllium.



Eight samples (21%) were, or may have been, ≥ the 0.2μg/m^3 action limit, while the 2μg/m^3 exposure limit was exceeded in only a single sample (3%). It can be seen that fully half of TWA results were either <0.05 or <0.10 μg/m^3.

Though useful, the forgoing analysis does not provide enough information to estimate the full range of past potential beryllium exposures. This document describes a model that can be used to estimate these exposures. Where information on actual beryllium exposures is available, there is reasonable agreement with the model.

METHODS

Two different approaches were employed to estimate past potential beryllium exposures:

1. Extrapolation from non-beryllium sample data.
2. Resuspension of removable surface contamination.

In most cases the first approach was used. The only limitation was the availability of sample data. By browsing through Fermilab's IH sample database, it was determined that adequate information existed for *grinding, welding, cutting,* *cleaning, sanding,* and *bulk handling*. These operations were performed on various materials, though metal often was involved.

The beryllium concentration was estimated by multiplying the known concentration of metal *X* with the ratio of densities, viz:

$$C_{Air}(Be) = C_{Air}(X) * \frac{r_{Be}}{r_X} = C_{Air}(X) * \frac{1.8\,gm/cm^3}{r_X}$$

For the purposes of estimating densities, iron (ρ = 7.9 gm/cm^3) and lead (ρ = 11.3 gm/cm^3) were the most frequently sampled materials. However, copper, concrete, bird droppings, beryllium, and beryllium-copper were also monitored.

Resuspension was used to estimate airborne exposures associated with *storage* of beryllium. This approach was used for two reasons: no aerosol data were available for quiescent storage and we possessed a great deal of surface contamination data for beryllium.

$$C_{Air}(Be) = C_{Surface}(Be) * RF = C_{Surface}(Be) * 10^{-5}/m$$

RF is the resuspension factor. Published values for this factor range from 10^{-8}/m to 10^{-2}/m, with a mean around 10^{-5}/m. In this exercise we used the mean: an overestimate relative to the NRC-recommended value of 10^{-6}/m (McKenzie-Carter, et al 1999). Surface contamination data were selected as those best representing storage-like surfaces. In most cases this turned out to be the inner surfaces of storage spaces (i.e., lockers, cabinets, and boxes). This is expected to result in an overestimate of personnel exposure since workers do not generally occupy the storage space itself.

Most of the concentration estimates apply to the person directly engaged in the indicated operation, i.e., the person likely to have the greatest exposure. Because the exposure criteria are so low, it is necessary to consider exposures to nearby workers as well. We will assume that nearby workers receive 10% of the exposure received by workers directly involved in the operation.

In addition to pure beryllium, personnel have also worked with beryllium-copper at Fermilab. This alloy may contain up to 4% beryllium. For the purposes of this exercise, we will assume that workers handling beryllium-copper receive 4% of the beryllium exposure as people handling pure beryllium.

As is often the case with unconstrained sampling, the data were log-normally distributed. For each type of operation a geometric mean and geometric standard deviation were calculated regarding results over the sample period (*i.e.,* as opposed to the TWA).

RESULTS

Table 1 contains summaries of pertinent data from Fermilab's Industrial Hygiene database. Sampled materials are indicated in the last column. Note that actual beryllium data is primarily used for the *storage* operation and this is for removable surface contamination. It was originally felt that separate use could be made of the results for all eight processes: *grinding, cutting, welding, sanding, cleaning*, *bulk handling, soldering,* and *storage*. However, the means for the first six of these are identical from a statistical standpoint. On the other hand, soldering and storage are statistically different from this group, as well as from each other ($p < 0.05$, t-test). The author subsequently proposed to the Virtual Industrial Hygiene Organization (VIHO) that a single mean be used to represent the first six processes. Though the VIHO members agreed with the analysis, they expressed a preference for keeping the data separate in hopes of improving acceptance in the minds of potentially exposed individuals (i.e., …these data pertain to my particular operation…).

Table 1 – Monitoring data and assumed values.

Operation	**Geometric mean raw data ROP (ug/m3)**	**Geometric standard deviation raw data ROP**	**Geometric mean Be-equivalent ROP (ug/m3)**	**Geometric standard deviation Be-equivalent ROP**	**Sample size**	**Sampled materials**
Grinding	400	17	***105***	***23***	54	Steel, copper, lead
Cutting	410	22	***100***	***27***	98	Lead, concrete, steel, plasma cutting
Welding	300	21	***69***	***20***	89	Steel, lead, copper, beryllium
Sanding	71	15	***16***	***14***	32	Steel, copper, lead, beryllium-copper
Cleaning	36	17	***13***	***34***	117	Lead, bird droppings, other
Bulk handling	34	7.0	***5.5***	***7.0***	160	Lead (mostly bricks)
Soldering	0.55	8.1	***0.12***	***8.1***	40	Lead, beryllium
Storage	-	-	***0.0038***	***38***	50	Beryllium (surface wipes)

ROP *refers to* ***R****esults* ***O****ver (sampled)* ***P****eriod.*

Table 2 contains estimated airborne concentrations of beryllium based on type of operation, worker proximity, and concentration of beryllium in the base metal.

Table 2 – Beryllium exposure estimates in mg/m^3.

Operation	Operator	Nearby worker	Operator	Nearby worker
Be concentration	***100%***	***100%***	***4%***	***4%***
Grinding	105	10.5	4.2	0.42
Cutting	100	10	4	0.4
Welding	69	6.9	2.76	0.276
Sanding	16	1.6	0.64	0.064
Cleaning	13	1.3	0.52	0.052
Bulk handling	5.5	0.55	0.22	0.022
Soldering	0.12	0.012	0.0048	0.00048
Storage	0.0038	0.00038	0.000152	0.0000152

DISCUSSION

The results in Table 2 suggest that resuspension from quiescent *storage* of beryllium and soldering on beryllium is unlikely present an exposure problem, regardless of proximity. This effectively eliminates a large population of people who merely walked by storage areas, as well as those who may have occasionally occupied storage areas (as long as they did not actually handle the beryllium). At the other end of the spectrum, *grinding, cutting, welding, sanding, cleaning*, and *bulk handling* present a range of exposure risks. Participation in many of these activities, whether pure beryllium or beryllium-copper, might cause people to be included in our beryllium-associated worker program. An exception would be people who are nearby active working of beryllium-copper for relatively brief periods.

These predictions are in relative agreement with known beryllium exposures. Examples include the following:

- Full-shift stacking of beryllium blocks can result in exposures as high as the 2 $\mu g/m^3$ TLV (Woodring 1985?). This is close to the 5.5 $\mu g/m^3$ predicted in Table 2 for *bulk handling*.
- Two Fermilab workers lightly sanded a total of 70 contacts consisting of 2% beryllium-copper prior to soldering. Their TWA exposures were ~0.2 and ~0.5 $\mu g/m^3$. Compare to results for *sanding*.
- None of Fermilab's air samples in beryllium storage areas have found detectable levels of beryllium (i.e., <0.1 $\mu g/m^3$**).** This is in agreement with the values in the *storage* row.
- A DOE component inspector and a number of clerical workers at Rocky Flats have developed CBD. Their only potential exposure was occasional passing through beryllium work/storage areas, inventorying/inspecting components and incidental handling of contaminated paperwork. (Wambach 2000). It is not difficult to imagine that their exposures, at least occasionally, were similar to those indicated in *bulk handling* above. As described in Safety Note

24, these concentrations are capable of producing CBD in sensitive individuals.

REFERENCES

M.A. McKenzie-Carter, M.D. Otis, M.E. Anderson, J.A. Roberts, R.L. Gotchy, R.A. Meck (1999). Radiological Assessments for clearance of equipment and materials from nuclear facilities, USNRC, (NUREG-1640 Volume 1).

VIHO (2000). Revised (Fermilab) Virtual Industrial Hygiene Organization Meeting Minutes 11/21/00. Item #2.

J. Woodring (1985?). Personal communication. ANL IH Group Leader.

P. Wambach (2000). Personal communication. DOE Be project manager.